

When the Sky Falls: Performing Initial Assessments of Bright Atmospheric Events

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Why? Space Situational Awareness (SSA)

- The ability to view, understand and predict the physical location of natural and manmade objects in orbit around the Earth
- Support government agencies through the provision of timely and accurate information and data regarding the space environment
- Hazards to infrastructure in orbit & on the ground
 - Collisions between objects in orbit
 - Harmful space weather
 - Potential strikes by natural objects



What qualifies as a “sky falling” event?

- Event appears on a major news network (CNN, ABC, etc)
- There are 50+ eye-witness reports
- NASA HQ inquires about a specific event
- The observed fireball end height is less than 35 km, and it decelerates to less than 10 km/s
 - Low + slow = possible meteorites
 - Would like to get searchers into area ASAP, especially if fireball is a Taurid (fragment of 2P/Encke) or a Geminid (fragment of 3200 Phaethon)

A different world

- As scientists, we spend considerable time analyzing data before publishing results
- This does not fit well in the 24/7 news cycle of the modern world
 - Just hours (not days) to respond to a significant fireball event
 - The populace expects governments to know what goes on in near-Earth space
- Our goal is to quickly “roughly characterize” events for the benefit of government officials, the media, and the general public
 - Base analysis on the data “at hand”
 - Be as accurate as possible
 - Always stipulate that results may change upon more detailed analysis
 - Do not be afraid to say “I don’t know”
 - Need a process and software (a “Chicken Little protocol”)

It does not take much...

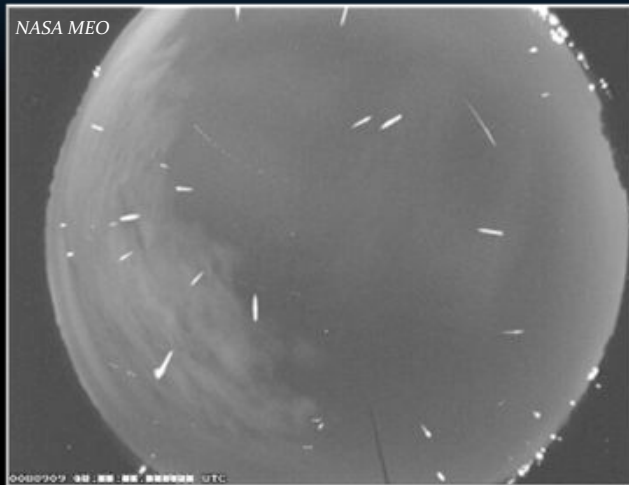
- Example text:

A fireball west of Jacksonville, FL on Saturday, Feb. 21st at 22:59:45 PM EST was detected by two all sky cameras, located in Melbourne, belonging to the Sky Sentinel Network.

The American Meteor Society has a write-up on this fireball at <http://www.amsmeteors.org/2015/02/florida-fireball-with-boom/>. There were over a hundred eyewitness reports, and the trajectory determined from these agrees fairly well with a crude triangulation performed using the Sky Sentinel videos. These videos and eyewitness reports indicate that the fireball started just east of Lake City and moved NE at about 40,000 miles per hour, burning up about 30 miles west of Jacksonville. The apparent brightness of the meteor permits a crude estimate of about a foot for the object's diameter, with a weight around 100 pounds.

- Provide a video or two, along with a ground track or something similar

Terminology



Fireballs or Bolides

- Bright meteors.
- Peak magnitude brighter than Venus, $m_{\text{app}} = -4$.



Superbolides

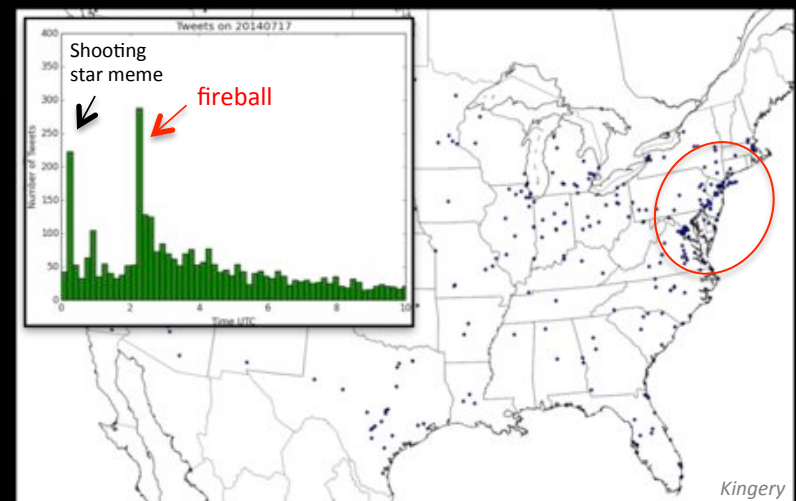
- VERY bright meteors.
- Peak magnitude brighter than the full Moon, $m_{\text{app}} = -17$.

When and Where

- Major news outlets
- American Meteor Society (www.amsmeteors.org)
- Latest Worldwide Meteor/Meteorite News (lunarmeteoritehunters.blogspot.com/)
- MeteorObs e-mail list (www.meteorobs.org)
- Facebook (www.facebook.com/NasaMeteorWatch)
- Twitter (1st tweet usually within seconds after event)
- YouTube



American Meteor Society fireball log



Data-mining Twitter

Space Rock, Space Junk, or Something Else?

- Events lasting minutes are reentering objects or aircraft contrails



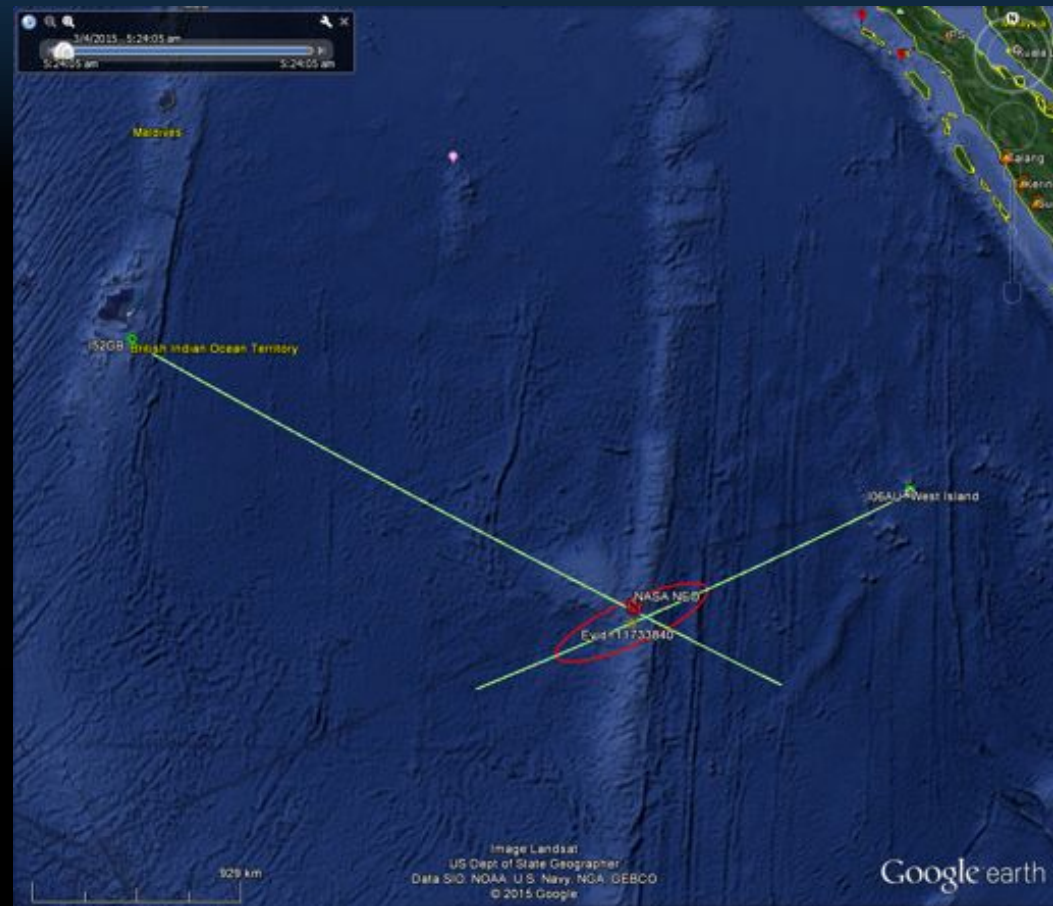
Chinese rocket body



Aircraft contrail

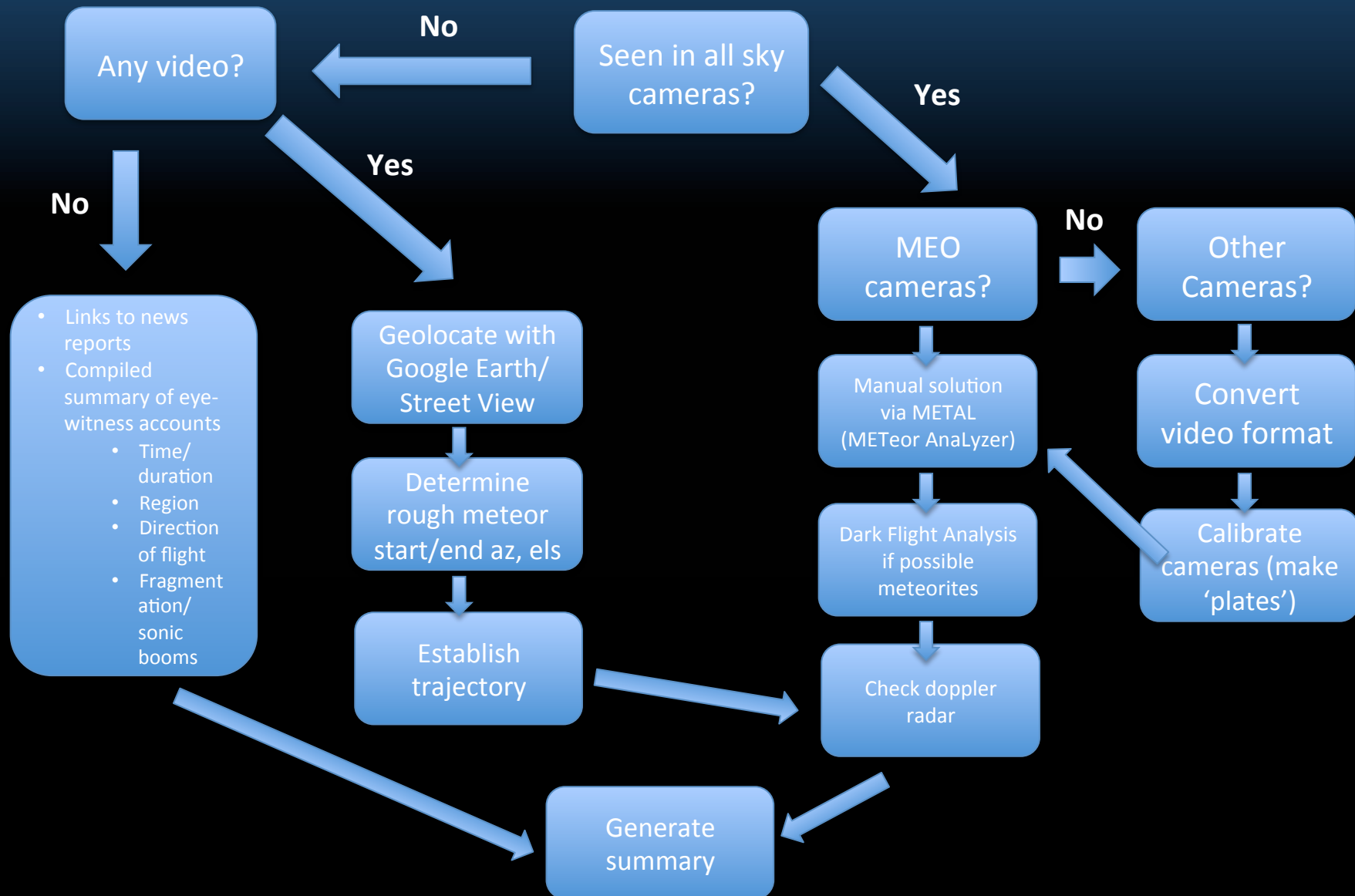
Superbolide?

- If so, query infrasound to establish location and energy
- Check seismic records
- Notify NEO office and coordinate response/outreach



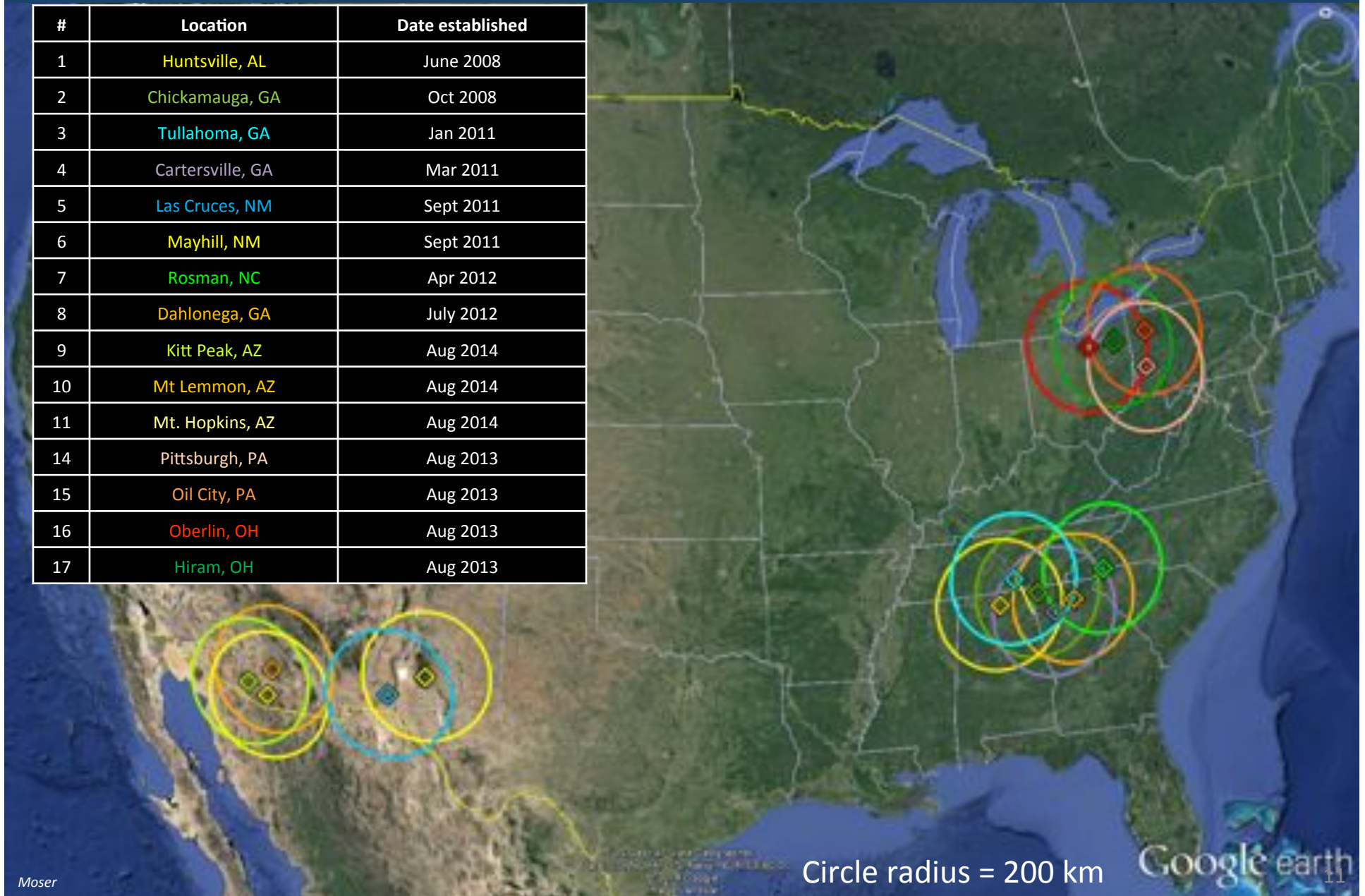
2015 Mar 04 event – 0.18 kT
(courtesy Pierrick Mialle, CTBTO)

Video work flow

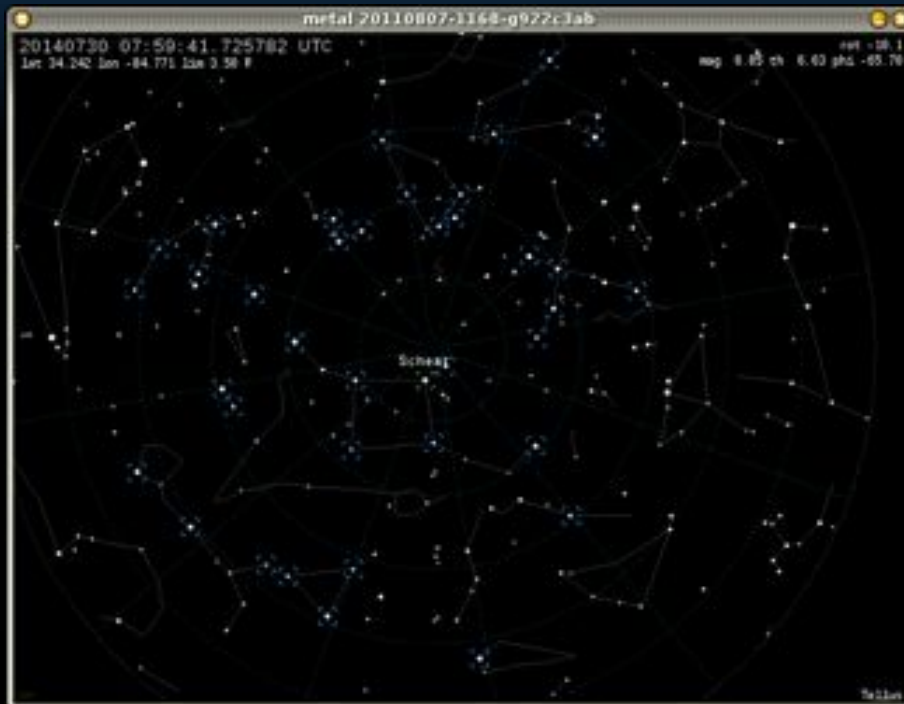


NASA All Sky Fireball Network Coverage

#	Location	Date established
1	Huntsville, AL	June 2008
2	Chickamauga, GA	Oct 2008
3	Tullahoma, GA	Jan 2011
4	Cartersville, GA	Mar 2011
5	Las Cruces, NM	Sept 2011
6	Mayhill, NM	Sept 2011
7	Rosman, NC	Apr 2012
8	Dahlonega, GA	July 2012
9	Kitt Peak, AZ	Aug 2014
10	Mt Lemmon, AZ	Aug 2014
11	Mt. Hopkins, AZ	Aug 2014
14	Pittsburgh, PA	Aug 2013
15	Oil City, PA	Aug 2013
16	Oberlin, OH	Aug 2013
17	Hiram, OH	Aug 2013



Images calibrated



Star map with catalog stars selected (blue)

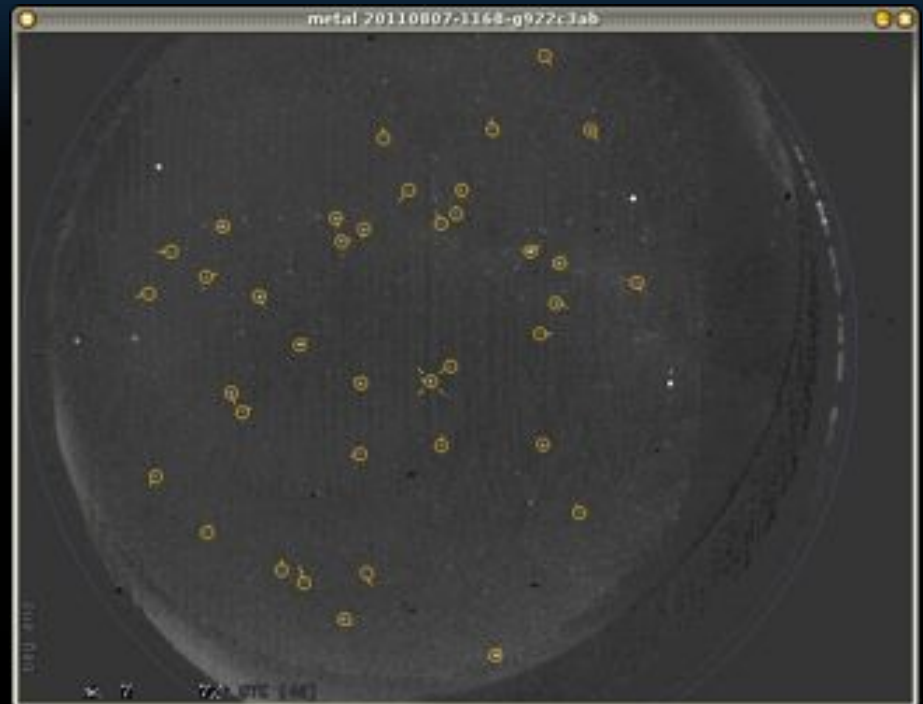
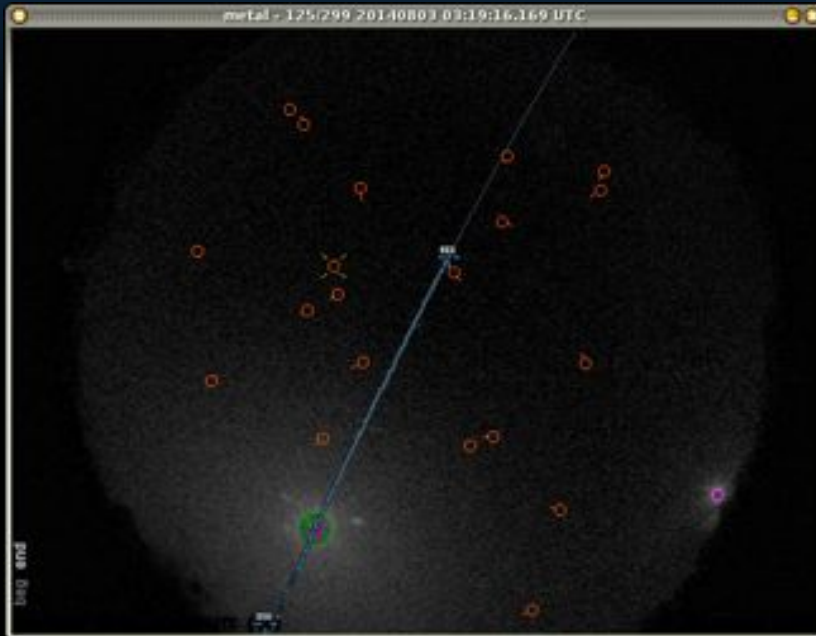


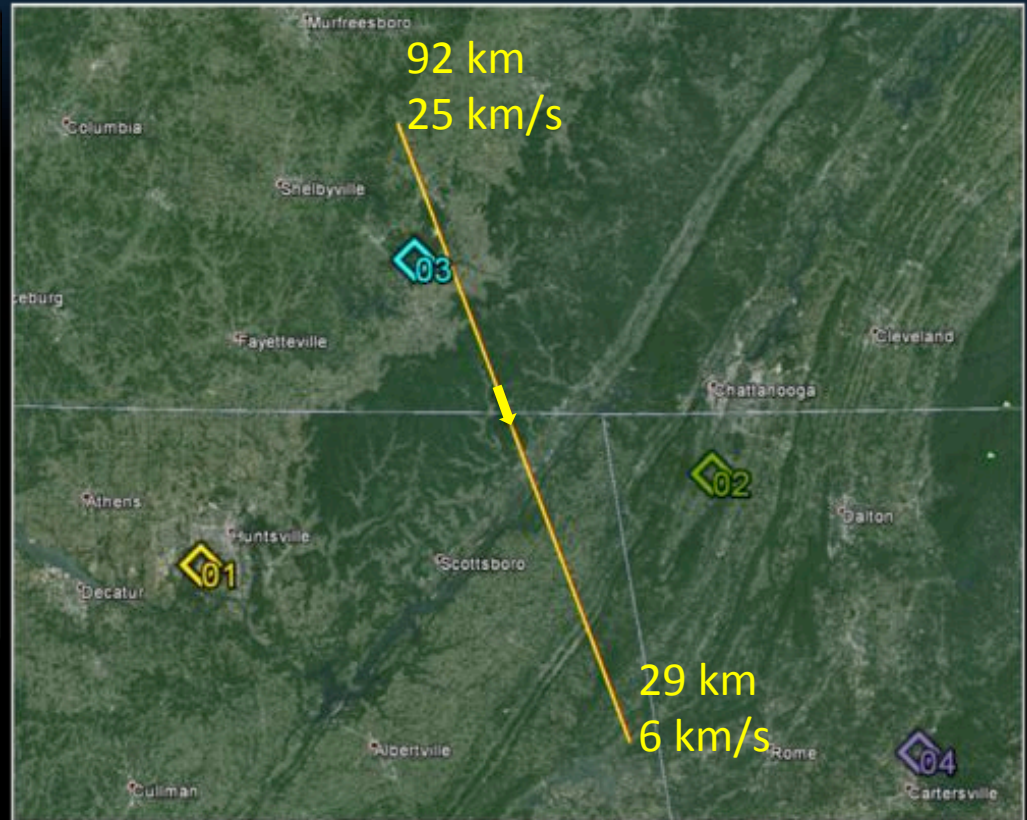
Image of night sky with corresponding stars selected (yellow)

Pixels coordinates are mapped to astronomical coordinates using stars.
Photometric offsets between observed stars & catalog stars are calculated.

Trajectory



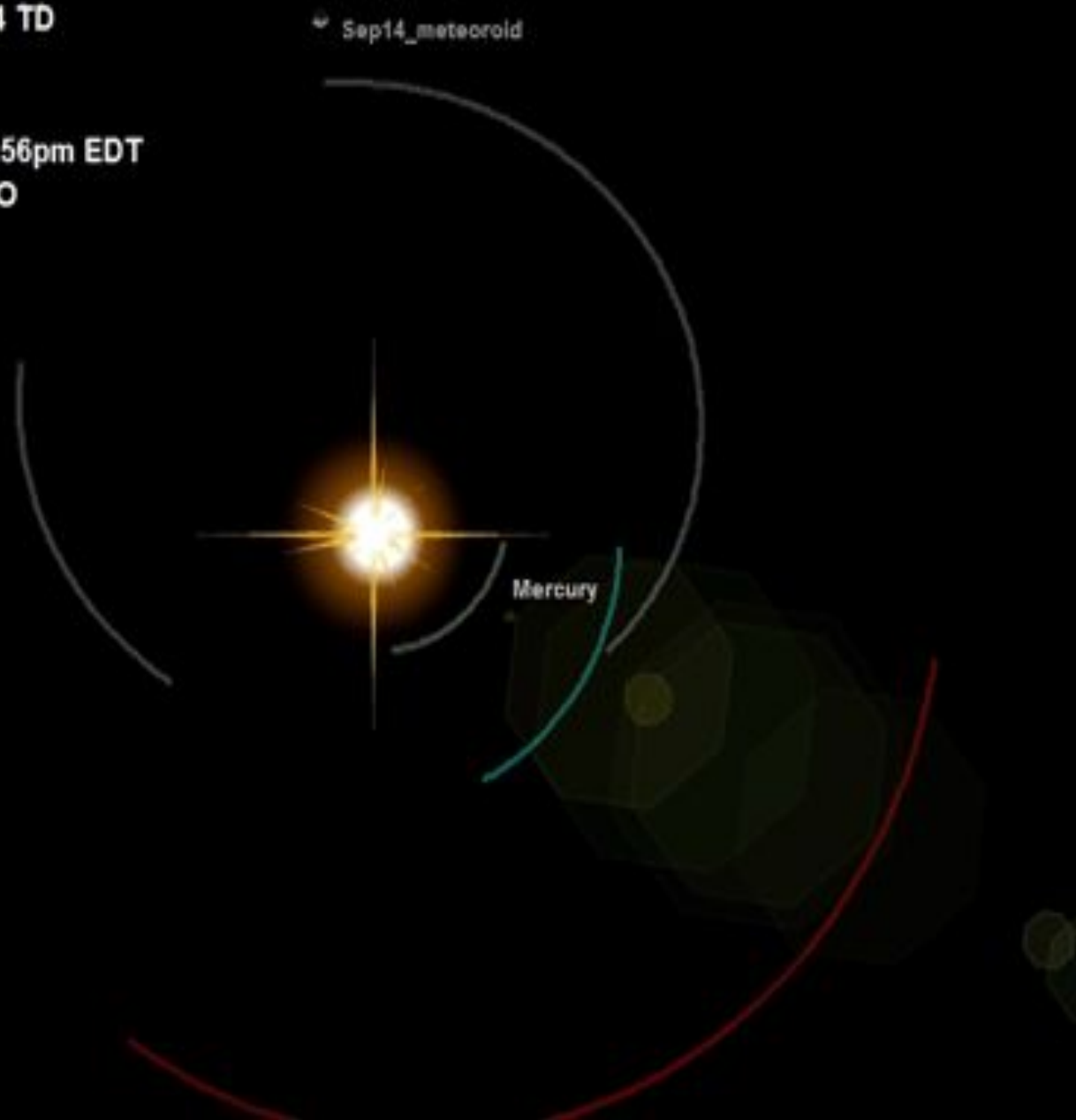
The meteor's path is selected video frame by frame (blue points); this is done for all stations



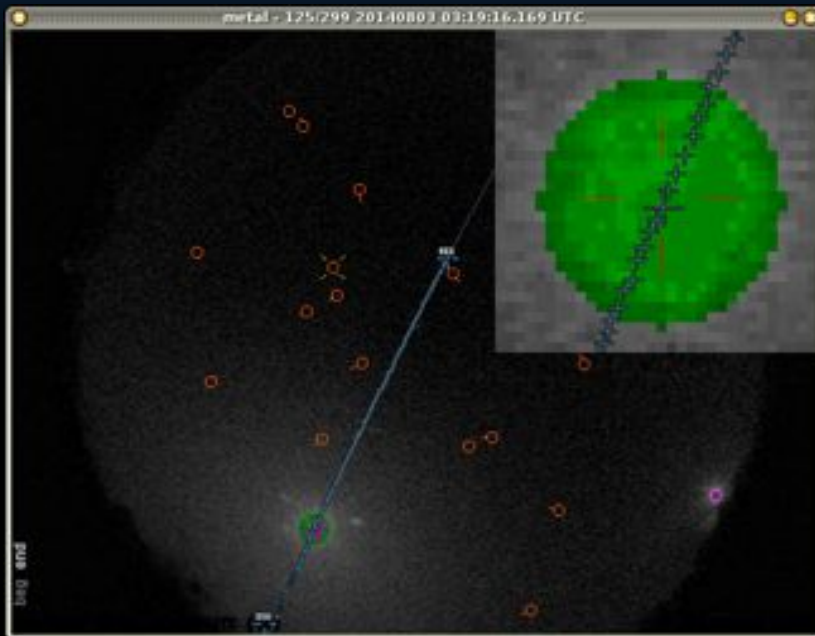
Final trajectory mapped with Google Earth

© 1994-2014 David L. Clark
2014/05/18 02:57:23.264 TD

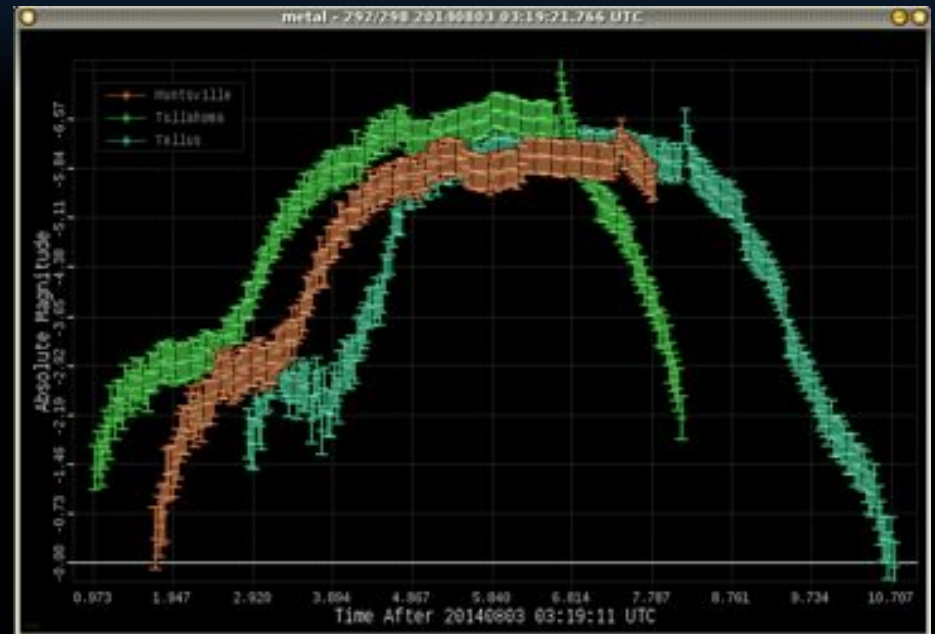
Northeastern fireball
September 14, 2014 10:56pm EDT
Prepared by: NASA MEO



Photometry

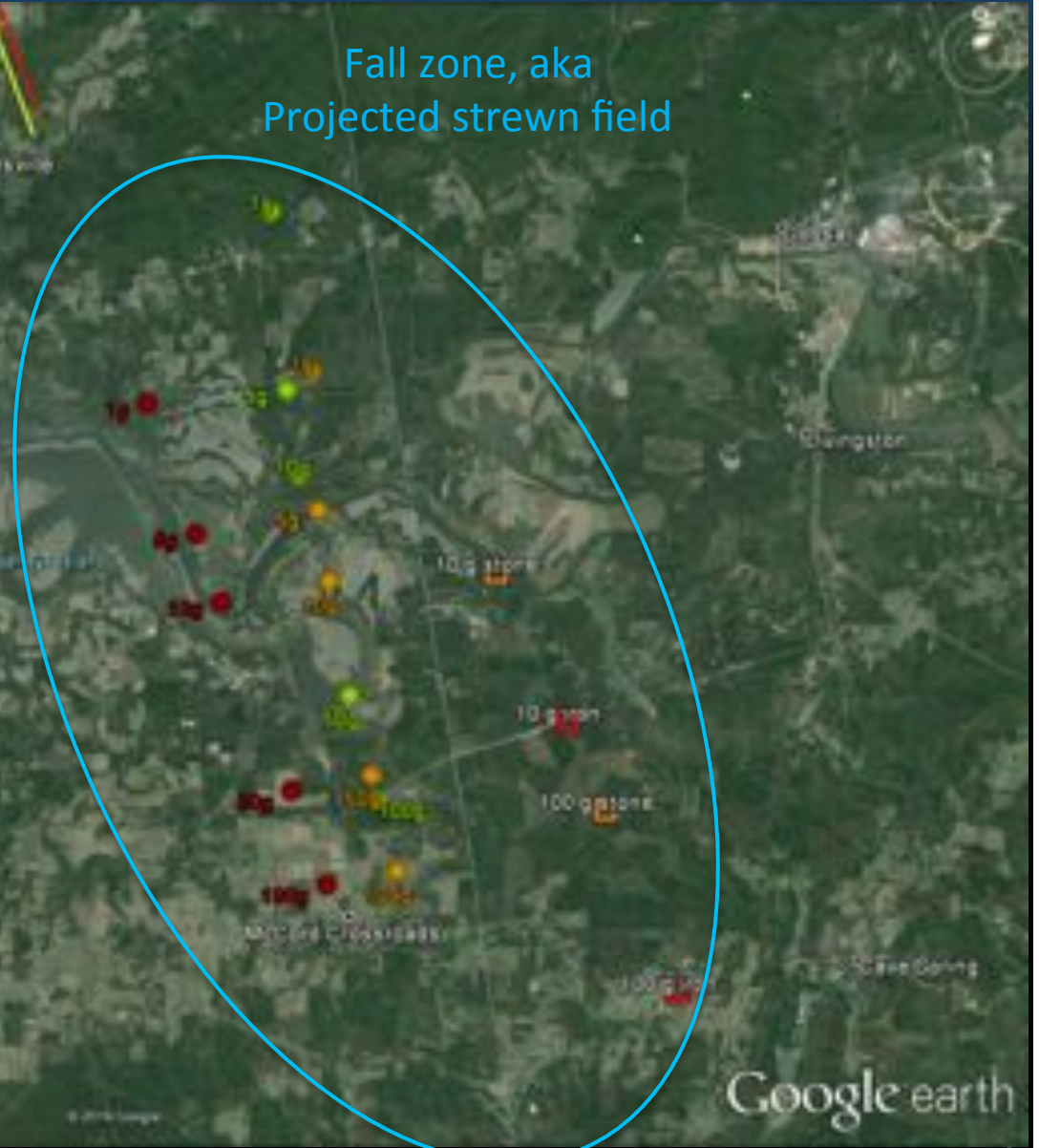
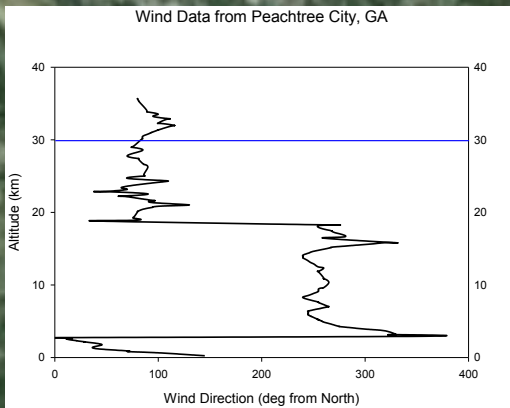
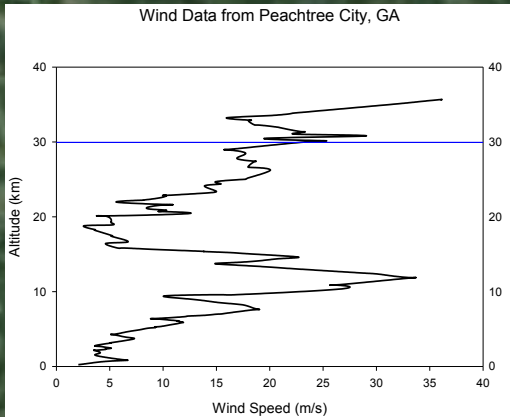


Pixels are selected (green) frame by frame to calculate the total light emitted; done for all stations



Light curve for each camera

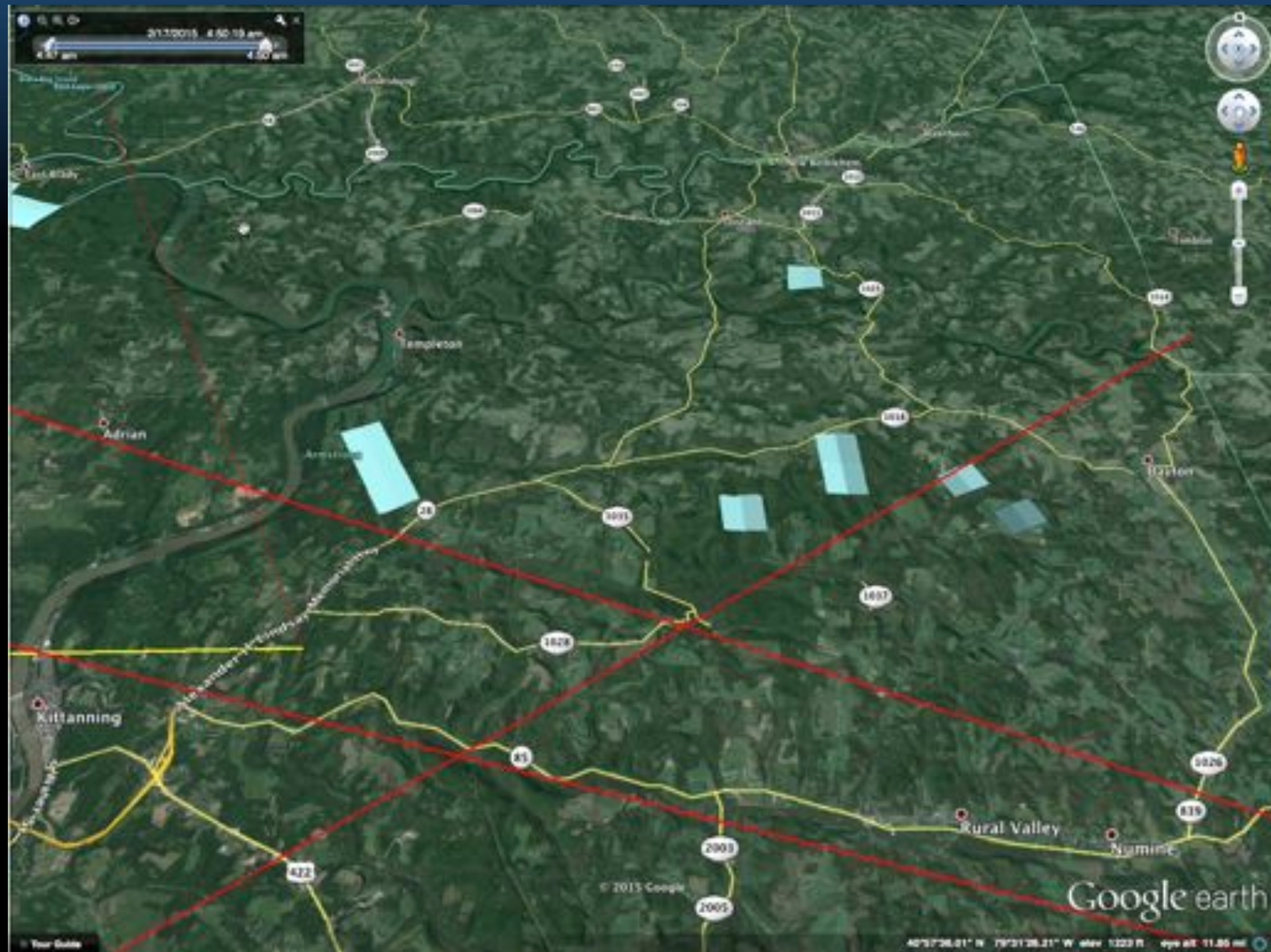
Dark flight modeling



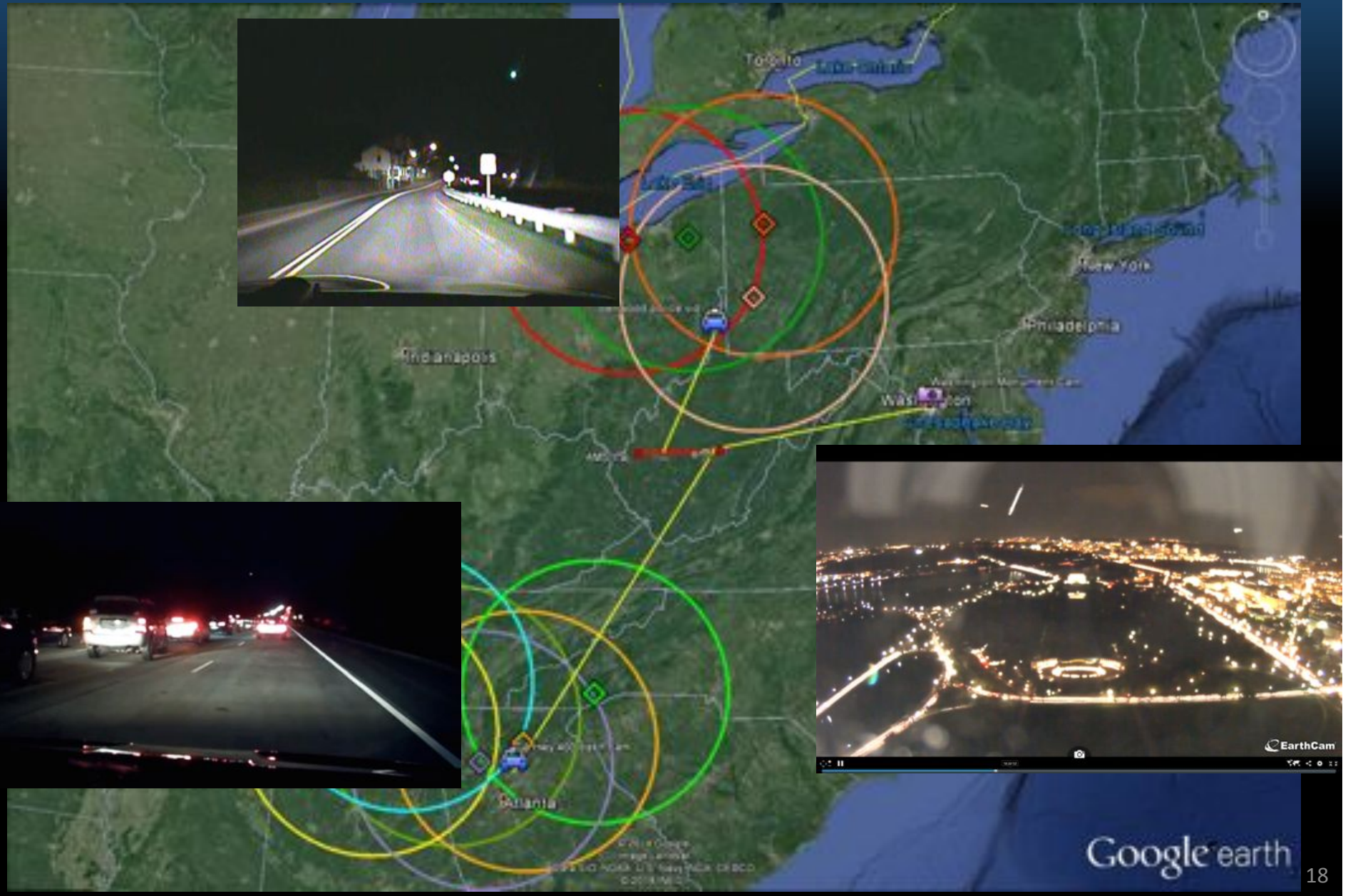
NASA model (stone): ● No wind ● Average wind ● Approx wind

Fries model:  Stone  Iron ¹⁶

Doppler radar



Other videos



In conclusion

- The 24/7 news cycle and expectations of officials and the public dictate a speedy (hours, not days) characterization of bright events
- This can be done by polling all sky networks, social media (Twitter, YouTube), infrasound, doppler radar, and web cams
 - But you need a good team at the ready
- Initial characterizations need not be very detailed:
 - Was it a space rock or space junk?
 - Where, how fast, and rough idea of size
 - Some vids, ground tracks, or links to sites like that of the AMS.